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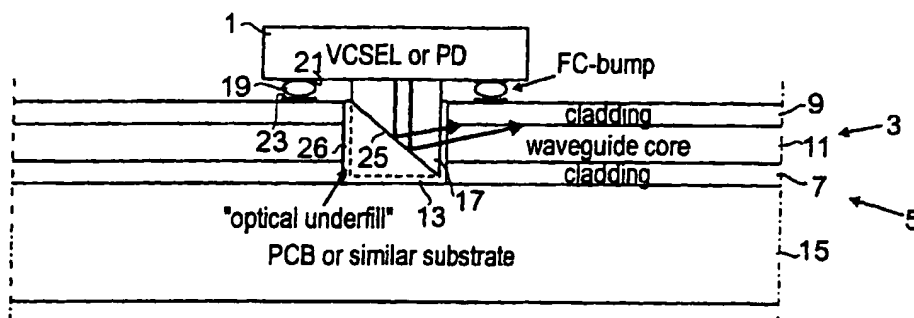
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(54) Title: MIRRORS FOR POLYMER WAVEGUIDES



(57) Abstract: In a substrate (15) such as a printed circuit board having optical wave guides (11, 7, 9) in its surface layers a mirror structure (17) is directly attached to a plate (1) and has a reflective, tilted surface (25). The mirror structure projects from an inner portion of the surface of the plate into a recess (13) in the substrate surface, the recess being made in the optical waveguide. The reflective surface thereby deflects light travelling in the waveguide. It can deflect light issued from the plate, in the case where the plate is e.g. a laser chip, to be injected into the waveguide. The reflective surface can also deflect light travelling in the waveguide to be received by the plate in the case where the plate has a photodetecting capability. The plate, e.g. a semiconductor chip, can be surface mounted to the substrate. For that purpose the plate has solder pads (21) cooperating with solder bumps (19) and such mounting can give the plate a very accurate position at the substrate surface. The plate can also be a dummy plate acting only as a carrier of the mirror structure that then can contain a plurality of reflecting surfaces placed on top of each other for deflecting light from one level of optical waveguides to another level and thus acts as an optical via.

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## MIRRORS FOR POLYMER WAVEGUIDES

## RELATED APPLICATIONS

This application claims priority and benefit from Swedish patent application No. 0202392-7, filed August 8, 2002, the entire teachings of which are incorporated herein by reference.

## 5 FIELD OF THE INVENTION

The present invention relates to mirrors for deflecting light propagating in waveguides at a surface of a substrate, such as polymer waveguides, and to methods of producing such mirrors.

## BACKGROUND

10 In for example optical devices having optical waveguides integrated in a substrate or applied to the surface of a substrate there is a need for devices for deflecting light between optical waveguides and between optical waveguides and transmitter and receiver elements. Such deflecting devices comprise mirrors that can for example be formed by oblique end surfaces of the optical waveguides.

For surface emitting laser (VCSEL) chips primarily coaxial coupling of light from the laser 15 chip to a light waveguide, an optical fiber or a waveguide in or on a substrate is used.

Mirrors for reflecting light between a waveguide and a transmitter or receiver chip are disclosed in U.S. patent 6,331,382 for Mats Robertsson. An oblique mirror structure inside a polymer waveguide is produced by irradiating the surface of the substrate containing the waveguide with strong laser light from a UV-excimer laser to ablate the polymer material of the substrate, 20 thereby producing an oblique slot, the walls of which can be coated with metal material to increase their reflecting capability or the whole recess filled with a reflecting material. The side-walls that are reflecting can be flat surfaces or surfaces having a simple curvature. However, the manufacture using UV-excimer laser ablating is technically difficult. Also, only one mirror or a few mirrors are produced at a time. Thus, since this method is not suited for mass manufacturing, the cost of each 25 mirror produced is relatively high. The metalization step is not simple and it is not easy to fill the whole recess with a reflecting material. If no metal material is used, the mirror surfaces produced are dielectric, i.e. light is reflected in the interface between materials of different refractive indices, and it is difficult to produce such reflecting surfaces having a high reflecting capability.

Mirrors formed by anisotropic etching of monocrystalline silicon substrates have been used 30 for coupling of light primarily between two adjacent optical devices such as a laser and a monitor diode, see e.g. U.S. patent 5,438,208. Only flat reflecting surfaces can be obtained. In U.S. patents 5,479,426 and 5,793,785 is disclosed how an oblique surface is produced at as a sidewall of a recess at the surface of a substrate, this surface used for reflecting light from a semiconductor laser to make the light be radiated perpendicularly away from the substrate.

A separate mirror element placed between a substrate and a holding device is disclosed in U.S. patent 6,236,788.

Photo-patternable polymer materials suitable for producing optical waveguides on top of various carriers are e.g. described in M. Robertsson, A. Dabek, G. Gustafsson, O.-J. Hagel, M. Popall, "New Patternable Dielectric and Optical Materials for MCM-L/D- and o/e-MCM-packaging", First IEEE Int. Symp. on Polymeric Electronics packaging, Oct. 26 - 30, 1997, Norrköping, Sweden, M.E. Robertsson et al.: "O/e-MCM Packaging with New, Patternable Dielectric and Optical Materials", at 48th Electronic Components and Technology Conference (ECTC'98), May 26 - 28, 1998 Seattle, U.S.A., and Mats Robertsson et al.: "Large area patterning of high density interconnects by novel UV-excimer lithography and photo patternable ORMOCER<sup>TM</sup>-dielectrica", Proc. IMAPS 2001, 13<sup>th</sup> European Microelectronics and Packaging Conference & Exhibition, Strasbourg, May 30 - June 1, 2001. In particular, the refractive indices of these materials, ORMOCER<sup>®</sup>, can be varied, the materials can be processed at relatively low temperatures of 120 - 180°C and have good etching characteristics.

When mounting optical components to the surface of a substrate, surface tension of the solder can be used for an accurate positioning, see e.g. the published British patent application 2 276 492 and the published U.S. patent application 2002/0071642.

#### SUMMARY

It is an object of the invention to provide devices for deflecting light propagating in optical waveguides.

It is another object of the invention to provide devices for deflecting light that can be manufactured in a relatively simple and non-costly way.

It is another object of the invention to provide methods for manufacturing devices for deflecting light that allow that a large number of devices are manufactured by processing a single carrier.

Thus generally, a mirror structure is provided that includes a reflective surface and is directly attached to a plate. The mirror structure projects from the plate, from a large surface thereof, preferably from an inner portion of the large surface, and is intended to be placed in a recess in a substrate surface containing at least one optical waveguide. The mirror structure can e.g. have a rectangular shape, in some case including an oblique free, reflecting surface. Advantageously, the reflective surface is the surface opposite the surface at which the mirror structure is attached to the surface of the substrate, also called a carrier, and it can consist of one or more portions, each portion located in an oblique angle to the large surface of the plate and thus to the substrate surface. The plate that preferably is a silicon chip or a semiconductor chip can be mounted to the surface of the

substrate using some surface mounting method for mounting electronic devices, such as the flip-chip method. For that purpose the plate has solder pads cooperating with solder bumps and such mounting can give the plate a very accurate position at the substrate surface. Such solder pads or solder bumps are advantageously located in pattern surrounding the mirror structure or recess  
5 respectively, for instance in a rectangular pattern or at the corners of a rectangle. Obviously, other mounting methods can be used allowing an accurate positioning, for example in the same way utilizing the surface tension of liquid solder.

The plate can be a semiconductor chip containing a device for issuing light from a large surface, such as a surface emitting laser structure or a light emitting diode or containing a device for  
10 receiving or detecting light.

The plate can be completely passive acting only as a carrier of the mirror structure that then can contain a plurality of reflecting surfaces placed on top of each other. Such a mirror structure can be used for deflecting light from one level of optical waveguides to another level and thus acts as an optical via.

15 The plate including the mirror structure can be produced from a large plate on which, in a sequence of processing steps, a large number of individual mirror structures are formed. The large plate is then split such as by sawing into small plates, each one having one or a few mirror structures attached to it. The processing steps can include coating the plate with a curable material, shaping the surface of this material and then curing it. The shaping can be made in a replication process bringing  
20 a tool having a shaped surface in contact with curable layer and then curing the layer. In the case where the curing is made by illuminating with some suitable energetic light such as UV-light or blue light the tool can be transparent to the energetic light allowing the curing to be made when the tool is still in contact with the curable material. The tool can have non-transparent portions allowing the material to be cured only in selected regions.

25 Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the methods, processes, instrumentalities and combinations particularly pointed out in the appended claims.

### 30 BRIEF DESCRIPTION OF THE DRAWINGS

While the novel features of the invention are set forth with particularity in the appended claims, a complete understanding of the invention, both as to organization and content, and of the above and other features thereof may be gained from and the invention will be better appreciated from a consideration of the following detailed description of non-limiting embodiments presented

hereinbelow with reference to the accompanying drawings, in which:

- Fig. 1 is a cross-sectional partial view of an optical waveguide assembly including a mirror structure attached to a semiconductor chip that includes a light emitting or light receiving element,
- Fig. 2 is a plan view of the portion of an optical waveguide assembly of Fig. 1,
- 5 - Fig. 3 is a cross-sectional view of a mirror structure attached to a semiconductor chip having a reflective surface including two flat segments,
- Figs. 4a - 4c are plan views illustrating various cases of deflecting light using a mirror structure having a reflective surface including two or four flat segments,
- Fig. 5 is a cross-sectional view of a mirror structure attached to a semiconductor chip having a  
10 filtering reflective surface,
- Fig. 6 is a cross-sectional view of a mirror structure attached to a semiconductor chip having a curved reflective surface for providing collimation or focusing,
- Fig. 7 is a view similar to Fig. 1 showing a mirror structure having a semi-reflecting surface,
- Fig. 8a is a cross-sectional part view of an optical waveguide assembly including a mirror structure  
15 attached to a semiconductor or dummy chip and acting as an optical via,
- Fig. 8a is a cross-sectional part view of an optical waveguide assembly including a mirror structure attached to a semiconductor chip that includes a light emitting or light receiving element, the mirror structure both acting as a mirror for deflecting to or from the chip and acting as an optical via,
- Fig. 9a is a plan view of the portion of an optical waveguide assembly of Fig. 8a,
- 20 - Figs. 9b - 9c are plan views illustrating cases of deflecting light using a mirror structure similar to that of Fig. 8 but having a lower reflective surface configured in other ways,
- Figs. 10a - 10f are cross-sectional part views illustrating steps in a process for manufacturing a mirror structure,
- Figs. 11a - 11e are cross-sectional part views illustrating steps in an alternative process for  
25 manufacturing a mirror structure,
- Figs. 11f - 11g are cross-sectional part views illustrating modifications of steps in the manufacturing process of Figs. 11a - 11e,
- Figs. 12a - 12c are cross-sectional part views illustrating steps in a further alternative process for manufacturing a mirror structure.

### 30 DETAILED DESCRIPTION

First, a device for interfacing a VCSEL or a VCSEL-array with optical waveguides will be described.

In Fig. 1 a cross-section of e.g. a surface emitting semiconductor laser (VCSEL) 1 coupled to an optical waveguide 3 is shown. The waveguide 3 is formed in the surface structure of an optical

board or plate 5 by patterned layers forming lower and upper claddings 7 and 9 and a waveguide core 11 located therebetween. The waveguide is thus parallel to the surface of the board and a recess 13, see also the view from above in Fig. 2, is made in the board down to a base or support layer 15, which e.g. can be a PCB substrate, of the board to expose the core 11 of the waveguide at a side surface of the recess. This side surface or side wall is flat, extends perpendicularly to the surface of the substrate 5 and to the longitudinal direction of the waveguide 3. The laser 1 is a semiconductor chip generally having the shape of a small rectangular plate comprising two opposite large surfaces and emits the laser light out of one of its large surfaces, the bottom surface in the figure.

A mirror structure 17 is attached to this large surface of the laser chip 1 and has the shape of a rectangular body standing out from the large surface so that the laser light passes downwards into the mirror structure from its top surface, perpendicularly to the large surface of the laser. The laser chip 1 is mounted to the surface of the board 5 so that the mirror structure projects down into the recess 13. Furthermore, the laser is mounted in such a way that it obtains an accurately defined position at the surface of the board and in particular in relation to the recess 13. An accurate mounting can be achieved by e.g. using flip-chip mounting comprising solder bumps 19 electrically and mechanically coupled to connection pads 21, 23 at the large bottom surface of the laser chip and at the board surface respectively.

The mirror structure 17 contains a mirror surface 25 and is made from mainly a material that is optically transparent to the light emitted from the laser 1. The mirror surface 25 is flat and is located in an oblique angle to deflect the light emitted by the laser in a vertical downward direction to an approximately horizontal direction, i.e. in a direction parallel to the surface of the board, so that the light from the laser enters the waveguide 3 and so that the center of the light beam hits the core 11 of the waveguide. Generally then, the mirror surface can be located in an angle of about  $45^\circ$  in relation to the large bottom surface of the laser chip 1 and thereby also in the same angle in relation to the surface of the board.

The mirror surface 25 can be formed as a surface separating two materials having different refractive indices, e.g. between a polymer and air, or be a metal surface, e.g. obtained by metalizing a sloping surface of a polymer material, such as by sputtering or CVD. In these cases the mirror structure can have the shape of a rectangular body cut off by the oblique reflecting surface.

The space between the mirror structure 17 and the walls of the recess 13 can be filled with a suitable material 26 that is transparent to the light emitted by the laser and generally to the light intended to travel in the waveguide. The material has suitably a refractive index selected to minimize losses of light passing the walls of the space, i.e. passing the lateral surface of the mirror structure 17 and the sidewalls of the recess 13. Such a material can be called an optical underfill and

can be a polymer material such as a transparent silicon rubber, an ORMOCER® inorganic-organic polymer or an acrylate-, epoxy- or other suitable polymer. It can be a material that hardens or can be cured to become solid or at least is stiff enough to also maintain the mirror structure 17 in the intended position given to it in mounting the laser chip 1 to the board.

5 The mirror structure 17 described above can obviously be used together with other optical components such as all components emitting light from the large surface of the component chip, for example light emitting diodes, and also all components such as photo diodes (PDs) or photo transistors capable of receiving or detecting light at their large surfaces.

Instead of the simple flat mirror surface 25 illustrated in Fig. 1, the mirror surface can be  
10 composed of a plurality of flat mirror segments, each of which located in an angle of about 45° to the horizontal and vertical directions. Thus, as seen in Fig. 3, two mirror segments 27 reflect light from the laser in two opposite directions, to two collinear waveguides, compare Fig. 1, being e.g. portions of a continuous straight waveguide that is interrupted by the recess 13. In the views from above in Figs. 4a, 4b and 4c some different cases of transmitting light via the mirror structure 17  
15 into waveguides can be seen. Thus, in Figs. 4a and 4b mirror surfaces having two flat surface portions are used to deflect light in two opposite directions. In the structure illustrated in Fig. 4c the mirror surface comprises four flat surface portions reflecting light in four perpendicular directions.

The mirror surface 25 can have a surface structure that acts in a filtering way so that when it is hit by light only light within a wavelength band is reflected, see the sectional view of Fig. 5. The  
20 mirror surface can be curved to act focusing on incoming parallel light that is reflecting or making incoming light formed to a parallel beam, see the sectional view of Fig. 6.

In the mirror structure 17 described above a fully reflecting mirror surface 25 is used. However, this mirror surface can be made to be only semireflecting, see Fig. 7, so that one share of the issued light is reflected to the waveguide 3 whereas the remaining share continues straightly  
25 through the mirror surface 29. This light then hits and is fully reflected by a lower mirror surface 31 to continue to propagate in a lower waveguide 3' having a core 11', a lower cladding 7' and a top cladding 9'.

A component for three-dimensional interconnection of optical waveguides at or in the surface of a substrate will now be described. Thus, the mirror structure described above comprising one  
30 fully reflecting mirror surface can be extended to comprise a plurality of fully reflecting flat, mirror surfaces located on top of each other and can then be used to redirect light from one optical waveguide to another optical waveguide located at a different level in the surface structure of a substrate, see Fig. 8a and the plan view of Fig. 9a. The extended mirror structure 17' is attached to one of the large surfaces, the bottom surface in the figure, of a plate 33. The plate can have same

shape as the semiconductor chip 1 and be made e.g. of silicon. The plate can be purely passive and acting only as a support of the mirror structure 17'. However, it can have soldering pads 21' like the laser or photodetector chip of Fig. 1 allowing it to be accurately positioned in a surface mounting method using soldering bumps 19' connecting to soldering pads 23' on the board surface.

5 The extended mirror structure 17' projects down into a recess 13' of the board 5. In the surface of the board at least two levels containing optical waveguides 3, 3' are provided, the waveguides being interrupted or ending at the recess exposing the cores 11, 11' and claddings 9, 11 and 9', 11' of the waveguides. The sidewalls of the recess at which the waveguides are exposed are flat and located in angles substantially perpendicular to the longitudinal directions of the waveguides, at least at the waveguide ends which will receive from or emit light into the waveguides. The mirror surfaces 25, 25' are as above arranged in oblique angles, e.g. of about 45°, to the vertical and horizontal directions. Other angles of the mirror surfaces can be used as long as the two mirrors form substantially the same angle to the horizontal or vertical directions, for example angles in the range of 30° to 60°, in particular for the case shown comprising two parallel mirror surfaces. The mirror surfaces are located so that e.g. light propagating in the upper waveguide 3 up to the recess 13' exits the waveguide and enters the mirror structure in which it is reflected by the top mirror surface 25. From this mirror surface the light passes downwards and is reflected by the lower mirror surface 25' by which it is reflected to take again a horizontal direction but at a different level. The light exits the mirror structure and enters the lower waveguide 3' in which it propagates to some other device, not shown.

If a flat surface of the board 5 is desired, the dummy chip 33 can be etched away provided that the transparent material 26 filling the space between the recess and the mirror structure sufficiently fixes the mirror structure in the correct position in the recess.

The mirror structure of Fig. 1 for reflecting light from or to the plate 1 can be combined with the structure of Fig. 8a to provide a mirror structure as illustrated in Fig. 8b. The top side of upper reflecting surface 25 here reflects the light coming from or destined for the plate 1 and its bottom side is part of the via structure for deflecting light travelling at different levels.

Also in the composite mirror structure the individual mirror surfaces can be composed of more than one flat surface such as having the shape illustrated in Fig. 3. They can be curved as in Fig. 5 if required and also be provided with a grating structure as in Fig. 4. More than two mirror surfaces can be arranged on top of each other. Some different cases of deflecting light incoming on a waveguide are illustrated in Figs. 9b and 9c. Thus, in Fig. 9b the incoming light is reflected to an antiparallel direction in a different level and in Fig. 9c the incoming light is reflected to take to opposite directions perpendicular to the direction of the incoming light.



The basic material of the mirror structure can be a suitable polymer material that is applied to the surface of e.g. a silicon wafer that can have already been processed to comprise a multitude of optical components such as lasers or light emitting diodes in the surface. The application of the material can be made using different mechanical methods such as by spinning, spraying or using a doctor blade to form a layer on top of the wafer, the thickness of the layer being appropriately selected. The layer is then processed to form the individual mirror structures and finally the wafer is split into the individual semiconductor chips with attached mirror structures.

In a manufacturing method a layer 41 of a UV-curable polymer material such as anOrmocer® is applied to the surface of a wafer 43 comprising a plurality of individual devices or plates 45 to be formed, see Fig. 10a, the device or plates including the soldering pads 21. The free surface of the layer is then deformed by pressing a tool 47 against the surface, the tool having recesses 49 that have one flat side 51 located in an angle of 45° in relation to the surface of the wafer 43. The tool is pressed to a position in which the lowermost parts thereof are in contact with the wafer surface. The tool is transparent to UV-light that is then used to cure the material of the layer 41, as seen in Fig. 10b, while the tool is still in the position pressing the layer. The tool 47 is then removed and the surface of the polymer material is coated with a layer 53 of a reflecting material such as a suitable metal that is applied by e.g. sputtering, see Fig. 10c. Another polymer layer 55 that suitable also is a Ormocer® material is then applied and cured, see Fig. 10d, the surface is covered with a mask layer 57 as seen in Fig. 10e, and the surface is etched in the windows of the mask to remove material down to the wafer surface. The mask layer 57 is then removed and the structure of Fig. 10f is obtained. The wafer is finally split at the division lines 58. In the step seen in Fig. 10d the uncured polymer layer can be again given a shaped surface structure by being moved in contact with a tool as in Figs. 10a and 10b to then form another mirror surface.

However, in the step of pressing the tool up to contact with the wafer it can be difficult to obtain a good filling of the spaces formed by the recesses 49. Then instead a tool as illustrated in Fig. 11a can be used having projections 59 with flat surfaces 61, the projections standing out from an otherwise flat bottom surface of the tool. The tool is then pressed against the non-cured polymer layer 41 that in this case has to be thicker. The pressing is stopped at a predetermined distance of the wafer surface in a position where the lowermost portions of the tool have not come into contact with the wafer as seen in Fig. 11b. The polymer is cured as above, the tool is removed, and the surface of the polymer is coated with a reflecting material 62, see Fig. 11c. Thereafter, the steps illustrated in Figs. 10d - 10f can be performed.

However, the reflecting surface 62 can be patterned directly after being applied. Then as seen in Fig. 11d a mask 63 can be applied covering only the oblique flat surfaces 65 of the cured polymer

layer and the reflecting material in the windows of the mask is then etched away to give the structure seen in Fig. 11e.

If the recesses 67 of the cured polymer layer formed by the tool have surfaces perpendicular to the wafer surfaces there may be a difficulty of applying the mask to have windows at a small distance of these vertical surfaces for etching away the reflecting material on these surfaces. Then instead the polymer layer can be formed to have tilted surfaces between the flat oblique surface as seen in Fig. 11g. The corresponding tool will then have the shape seen in Fig. 11f.

After the steps illustrated in Figs. 11e and after etching in the mask windows of the structure in Fig. 10g the steps illustrated in Figs. 10d - 10f can be performed.

10 In another embodiment the tool 47 can have portions of its pressing surface that are not transparent to the UV-light used for curing it. Such a tool is seen in Fig. 12a where the portions of the pressing surface between the projections are covered with a non-transparent layer 69, such as a metal layer. Then only the portions of the uncured polymer layer located beneath the transparent portions of the tool will be cured. If the UV-light is incoming to the tool in a sufficiently parallel beam and perpendicularly to the wafer surface then only the polymer portions beneath the oblique surfaces are cured and after removing the uncured portions of the polymer layer a structure as seen in Fig. 12b is obtained.

After the steps illustrated in Fig. 12b the steps of Figs. 10c - 10f or the steps illustrated in Figs. 11c - 11e can be performed.

20 A selective coating process can be obtained by using a shadow mask 71 placed at a small distance of the surface of the cured layer as seen in Fig. 12c. The mask has windows 73 placed at the oblique surfaces to be coated and for an appropriate position of these windows and for a sufficiently small distance of the polymer layer substantially only the oblique surfaces will obtain a reflective coating. The wafer can in this stage if desired be split into individual chips carrying mirror structures having free oblique surfaces formed at the layer producing the reflections. The chips need no further processing and can be used as is illustrated in Fig. 1.

It should be understood herein and in the claims hereof that such terms as "upper" and "lower", "top" and "bottom" and the like have been used for illustration purposes only, in order to provide a clear and understandable description and claiming of the invention. Such terms are not in any way to be construed as limiting, because the devices of invention are omni-directional in use as can be understood by their various uses in different application fields.

While specific embodiments of the invention have been illustrated and described herein, it is realized that numerous additional advantages, modifications and changes will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific

details, representative devices and illustrated examples shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents. It is therefore to be understood that the appended claims are intended to cover all such modifications and changes as  
5 fall within a true spirit and scope of the invention.

11  
CLAIMS

1. A reflective device including a plate, in particular a silicon chip or a semiconductor chip, having a large surface opposite another large surface, **characterized by** a mirror structure attached to the plate at said large surface and projecting from an inner portion of said large surface, the mirror  
5 structure comprising a first surface at which it is attached to the large surface of the plate and a second surface opposite the first surface, the second surface being reflective to light and located in an oblique angle or oblique angles to said large surface of the plate, the second surface intended for reflecting light to or from an optical waveguide end located at a side of the mirror structure, in particular for reflecting light incoming in a direction or directions substantially parallel to the plate  
10 surface to a direction substantially perpendicular to the large surface of the plate or to a direction at least forming a relatively large angle to the large surface of the plate and/or reflecting light incoming to the reflective surface in a direction substantially perpendicular to the plate surface or at least forming a relatively large angle to the large surface of the plate to a direction or directions substantially parallel to the plate surface.

15 2. A reflective device according to claim 1, **characterized by** a semiconductor device emitting or receiving light at the large surface of the plate, the reflective surface arranged for reflecting the light emitted or received by the semiconductor device.

3. A reflective device according to claim 1, **characterized in** that the mirror structure comprises a polymer material transparent to the light.

20 4. A reflective device according to claim 3, **characterized in** that the polymer material comprises Ormocer®.

5. A reflective device according to claim 1, **characterized in** that the reflective second surface is formed at an interface between a solid material and air.

6. A reflective device according to claim 1, **characterized in** that the reflective second surface  
25 is formed at an interface between portions of transparent materials having different refractive indices.

7. A reflective device according to claim 1, **characterized in** that the reflective second surface is formed at or by a reflective coating of a surface of a portion of a material transparent to the light.

8. A reflective device according to claim 1, **characterized in** that the reflective second surface  
30 is formed at or by a reflective coating located at an interface between two portions of material transparent to light.

9. A reflective device according to claim 1, **characterized by** solder pads at the plate surface for positioning, by the surface tension of solder used in soldering the plate to the surface of a substrate containing optical waveguides, the plate in an accurate position at the substrate surface in

relation to the optical waveguides and fixing the plate in this position.

10. A reflective device according to claim 9, **characterized in** that the solder pads are arranged in a pattern surrounding the mirror structure.

11. A reflective device according to claim 1, **characterized in** that it comprises at least two  
5 reflective surfaces located above each other and forming the same angle to the plate surface, the reflective surfaces cooperating to deflect light incoming to a first one of the reflective surfaces in a direction parallel to the plate surface to the second reflective surface that deflects the light to again take a direction parallel to the plate surface but at a different level from the plate surface.

12. A method of manufacturing a reflective component, **characterized by** the steps of:

- 10 - providing a plate, in particular a silicon chip or a semiconductor chip, having a large surface located opposite another large surface,  
- attaching a mirror structure to the plate at said large surface to project from an inner portion of said surface, the mirror structure comprising a first surface at which it is attached to the plate and a second surface opposite the first surface, the second surface being reflective and located in an  
15 oblique angle or oblique angles to the surface of the plate for reflecting light coming from or transmitted into an optical waveguide end located at a side of the mirror structure, in particular for reflecting light incoming to reflective second surface in a direction or directions substantially parallel to the plate surface to a direction substantially perpendicular to the large surface of the plate or to a direction at least forming a relatively large angle to the large surface of the plate and/or for  
20 reflecting light incoming to the reflective second surface in a direction substantially perpendicular to the large surface of the plate or at least forming a relatively large angle to the large surface of the plate to a direction or directions substantially parallel to the large surface of the plate.

13. A method according to claim 12, **characterized in** that the step of attaching the mirror structure comprises:

- 25 - applying a curable polymer material to the large surface of the plate to form an uncured polymer layer,  
- shaping the uncured layer to have a surface area located in an oblique angle, and  
- curing the uncured layer.

14. A method according to claim 13, **characterized in** that the shaping is made by pressing a  
30 tool having a profiled pressing surface to come in contact with the uncured layer.

15. A method according to claim 14, **characterized in** that in the pressing, the tool is moved up to a predetermined distance of the large surface of the plate.

16. A method according to claim 14, **characterized in** that the tool is transparent to curing light, in particular UV-light, and that the curing is made directing the curing light through the tool

while in contact with the uncured layer.

17. A method according to claim 14, **characterized in** that the tool is transparent to curing light, in particular UV-light, only in selected areas where the reflective surfaces are to be formed and that the curing is made directing curing light through the tool while in contact with the uncured  
5 layer, curing only portions of the uncured layer below the areas where the reflective surfaces are formed or are to be formed, and then removing the uncured portions of the layer.

18. A method according to claim 14, **characterized in** that after curing the layer the surface of the layer is coated with a material to obtain a reflecting surface coating.

19. A method according to claim 18, **characterized in** that the reflecting surface coating is  
10 patterned by first applying a mask layer to the coating, etching away the coating in windows of the mask and then removing the mask layer.

20. An optical waveguide assembly including

- a carrier having at least one optical waveguide in or at a surface for conducting light, and
- a plate, in particular a silicon chip or a semiconductor chip, mounted to the carrier surface,

15 **characterized by**

- a mirror structure attached to the plate at a large surface thereof and projecting from the surface, the mirror structure comprising at least one reflective surface located in an oblique angle to the large surface of the plate and reflecting light incoming to reflective surface in a direction substantially parallel to the large surface of the plate to a direction substantially perpendicular to the large surface  
20 of the plate or at least forming a relatively large angle to the large surface of the plate or reflecting light incoming to the reflective surface in a direction substantially perpendicular to the large surface of the plate or at least forming a relatively large angle to the large surface of the plate to a direction substantially parallel to the large surface of the plate, and
- a recess in the carrier surface having a sidewall at which an optical waveguide ends, the plate being  
25 mounted at the recess making the mirror structure project into the recess to deflect light from or into the optical waveguide.

21. An assembly according to claim 20, **characterized by**

- solder pads on the large surface of the plate,
- solder pads located on the carrier surface at the recess,
- 30 - solder connecting the solder pads on the plate surface and on the carrier surface with each other, the solder allowing positioning, by the surface tension of the solder in a soldering process, the plate in an accurate position at the carrier surface in relation to the optical waveguides and fixing the plate in this position.

22. An assembly according to claim 21, **characterized in** that the solder pads on the large

surface of the plate are located in a pattern surrounding the mirror structure.

23. An assembly according to claim 21, **characterized in** that the solder pads on the carrier surface plate are located in a pattern surrounding the recess.

24. An assembly according to claim 20, **characterized in** that the mirror structure comprises  
5 at least two reflective surfaces located above each other and forming the same angle to the large surface of the plate, the reflective surfaces cooperating to deflect light incoming from a first optical waveguide of the carrier to a first one of the reflective surfaces to the second reflective surface deflecting the light to a second optical waveguide of the carrier.

25. An assembly according to claim 20, **characterized in** that the space between the sidewalls  
10 of the recess and the mirror structure is filled with a material transparent to the light for which the optical waveguide is intended.

1/10

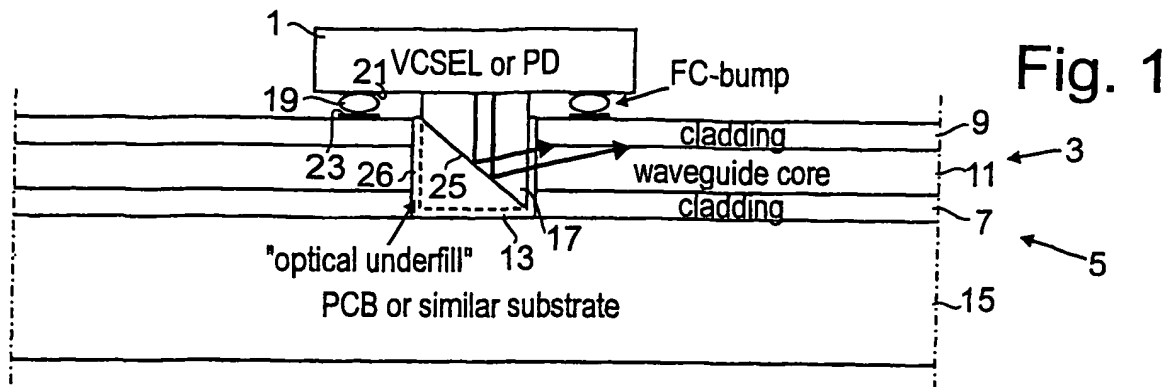
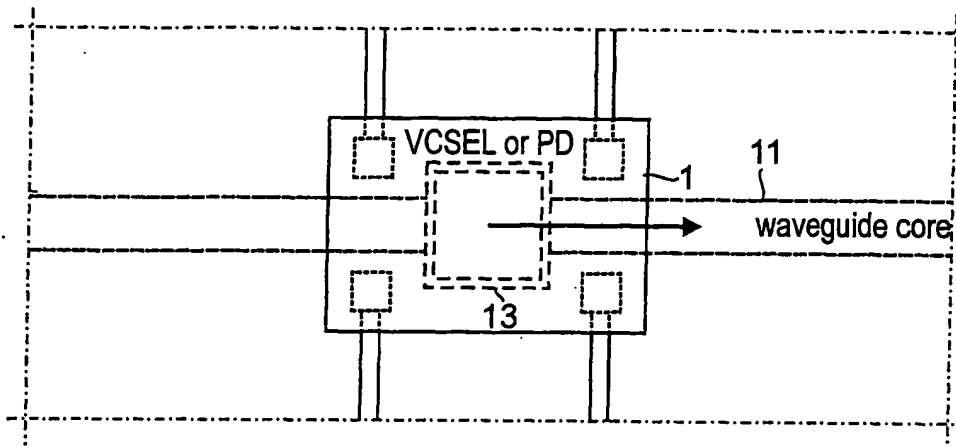
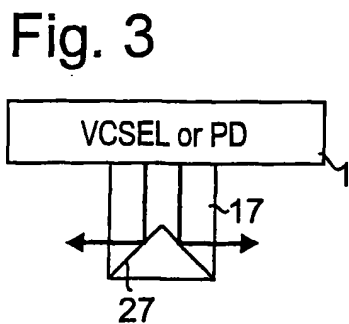


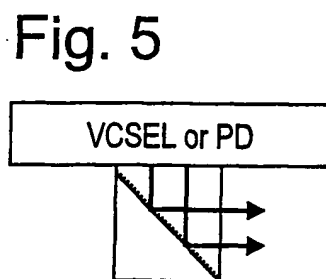
Fig. 1



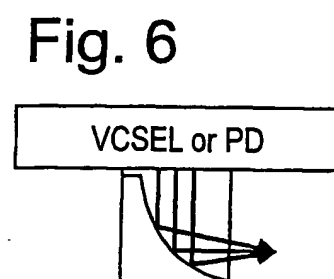
**Fig. 2**



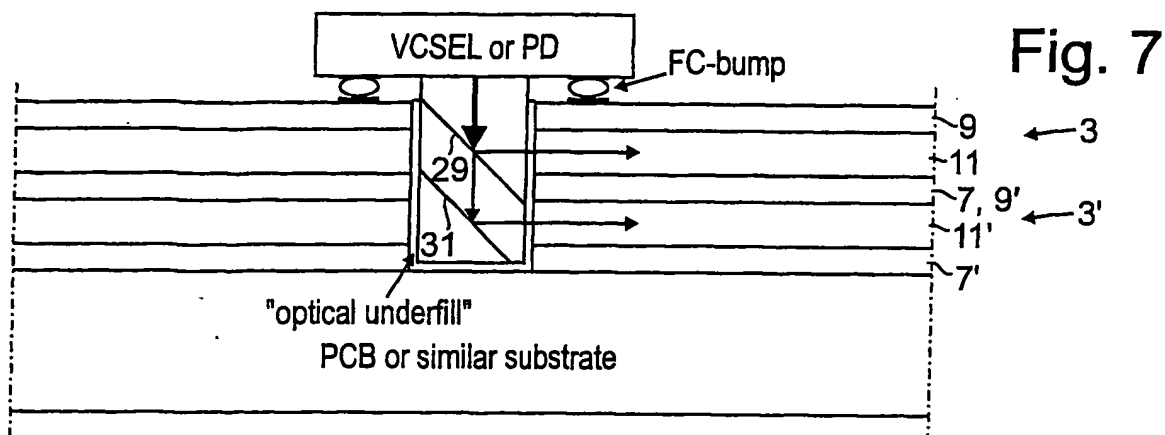
**Fig. 3**



**Fig. 5**



**Fig. 6**



**Fig. 7**



2/10

Fig. 4a

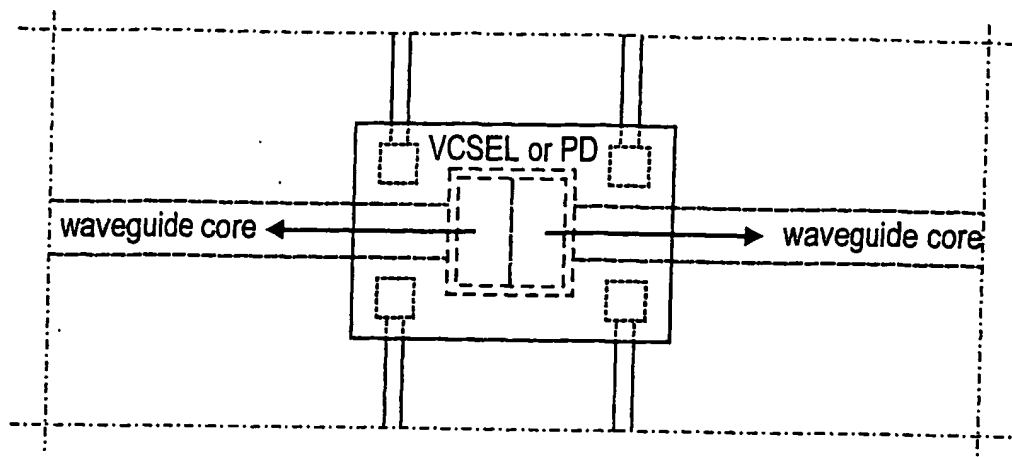


Fig. 4b

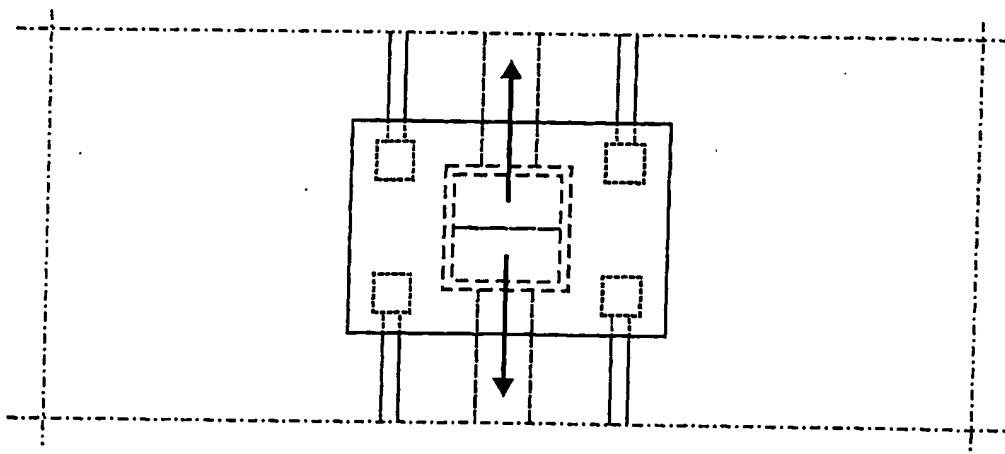
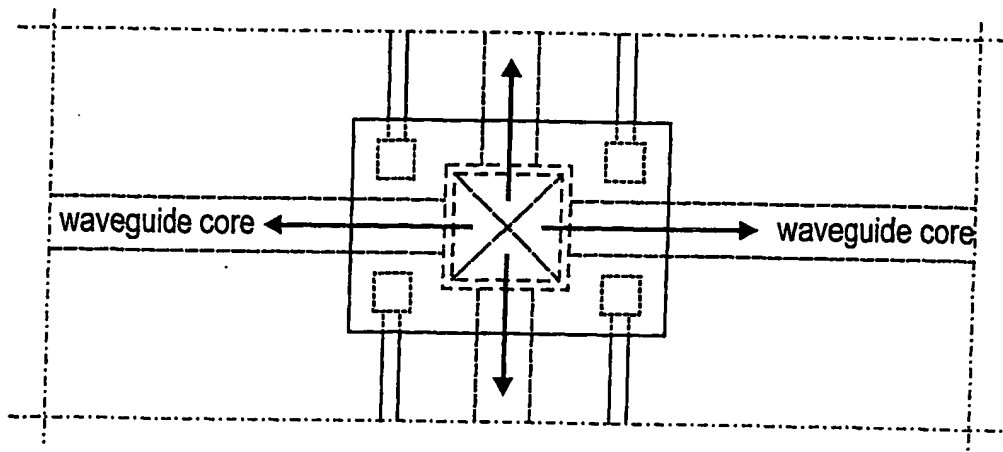


Fig. 4c



3/10

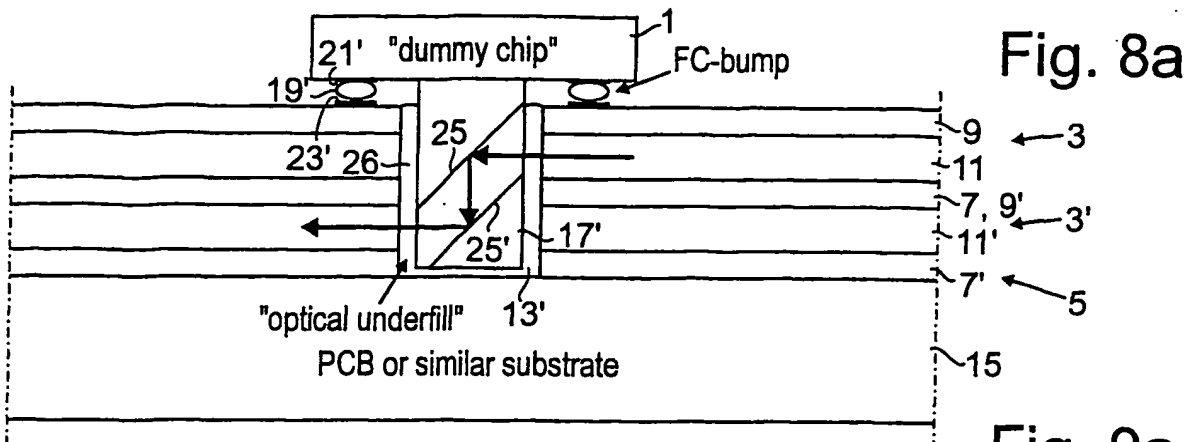


Fig. 8a

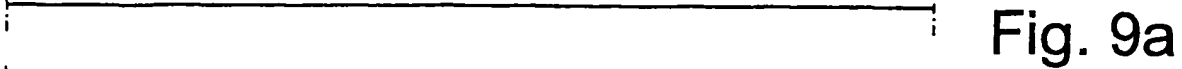
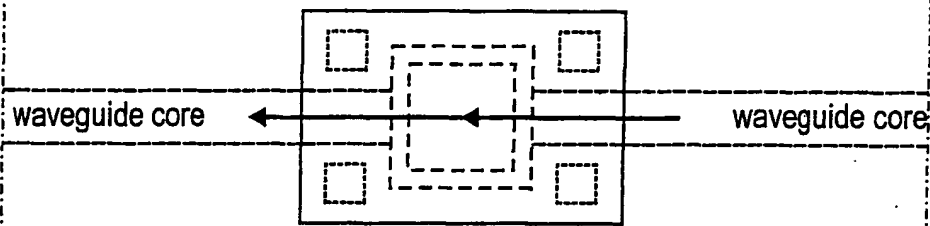


Fig. 9a



**Fig. 9b**

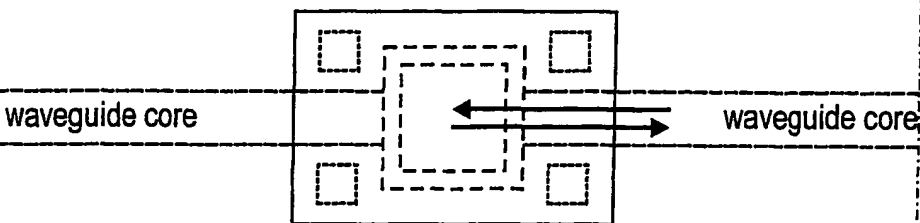


Fig. 9c

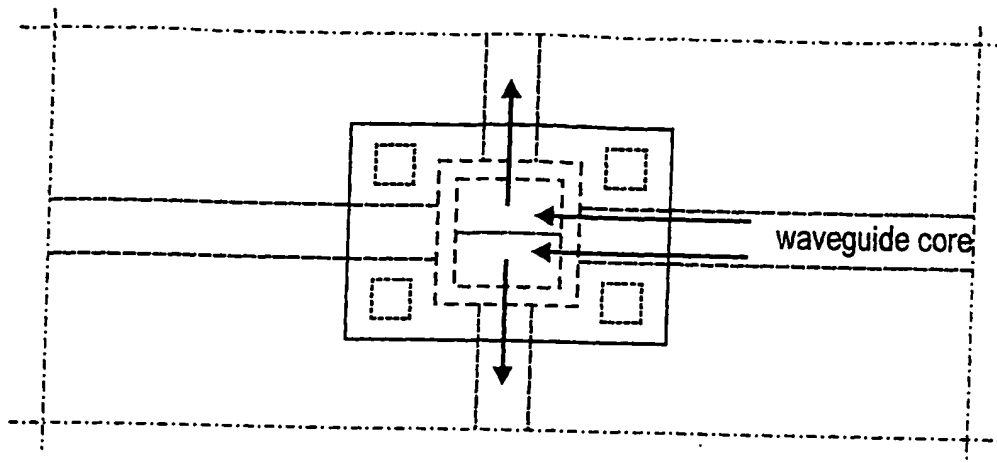
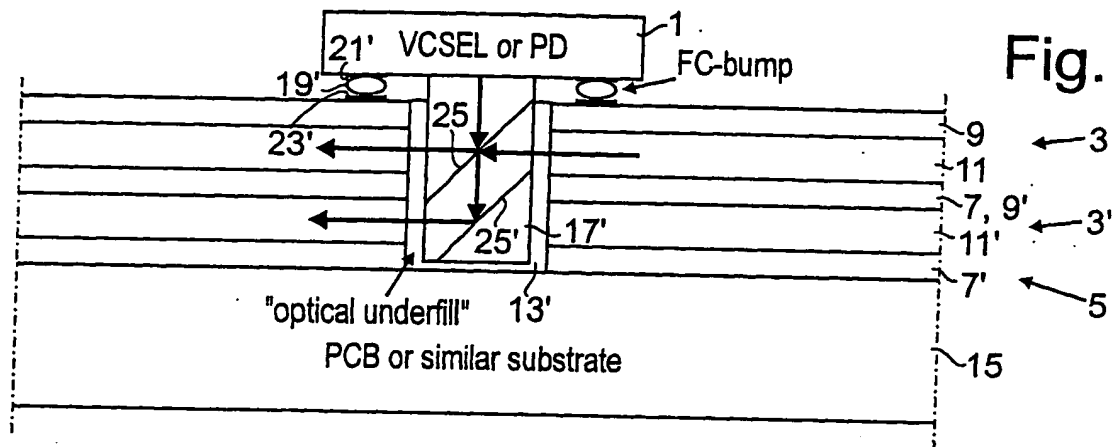


Fig. 8b



5/10

Fig. 10a

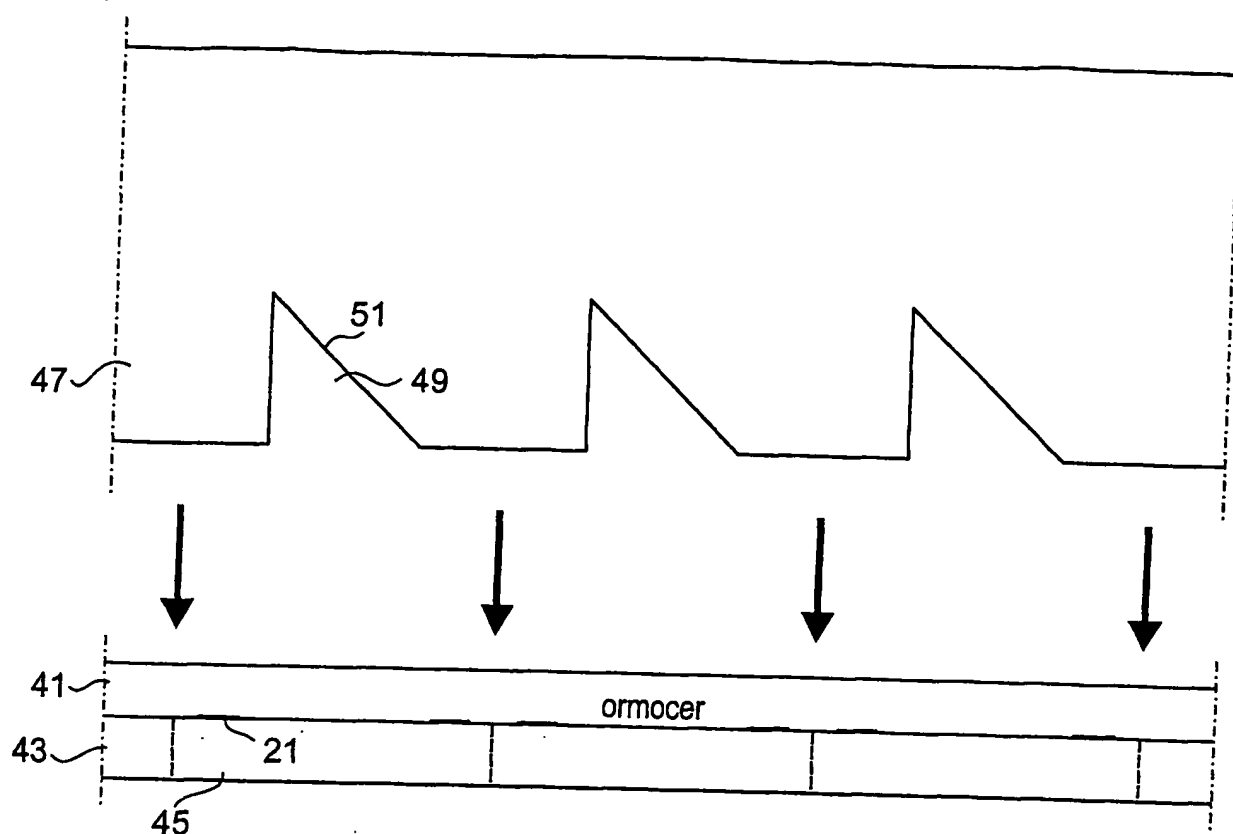


Fig. 10b

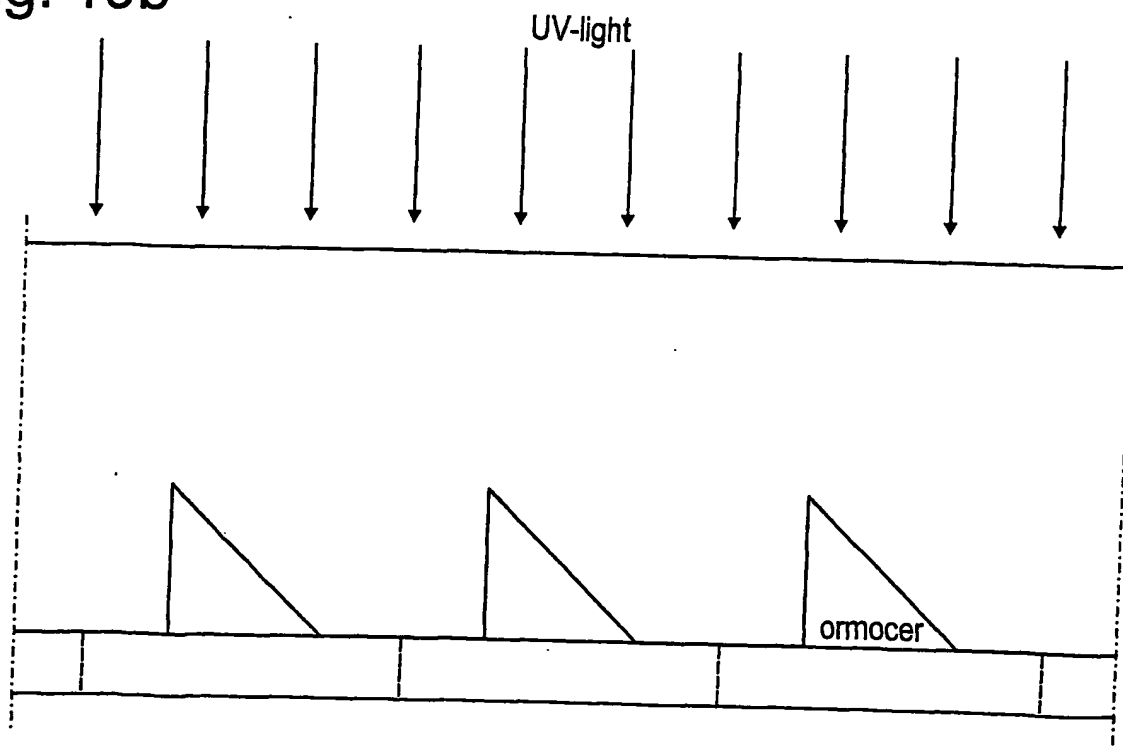


Fig. 10c

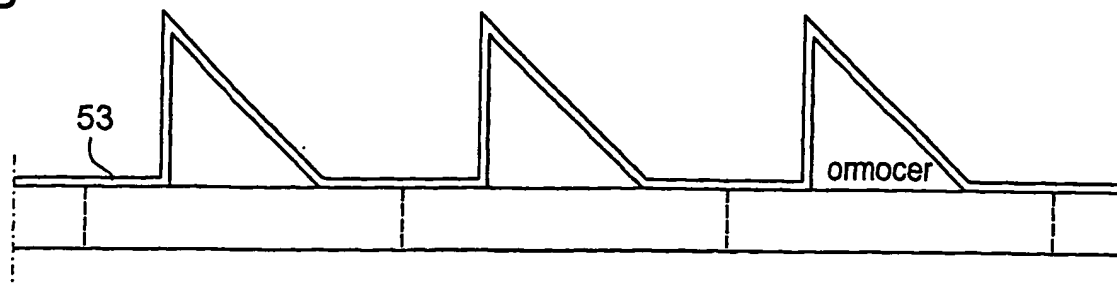


Fig. 10d

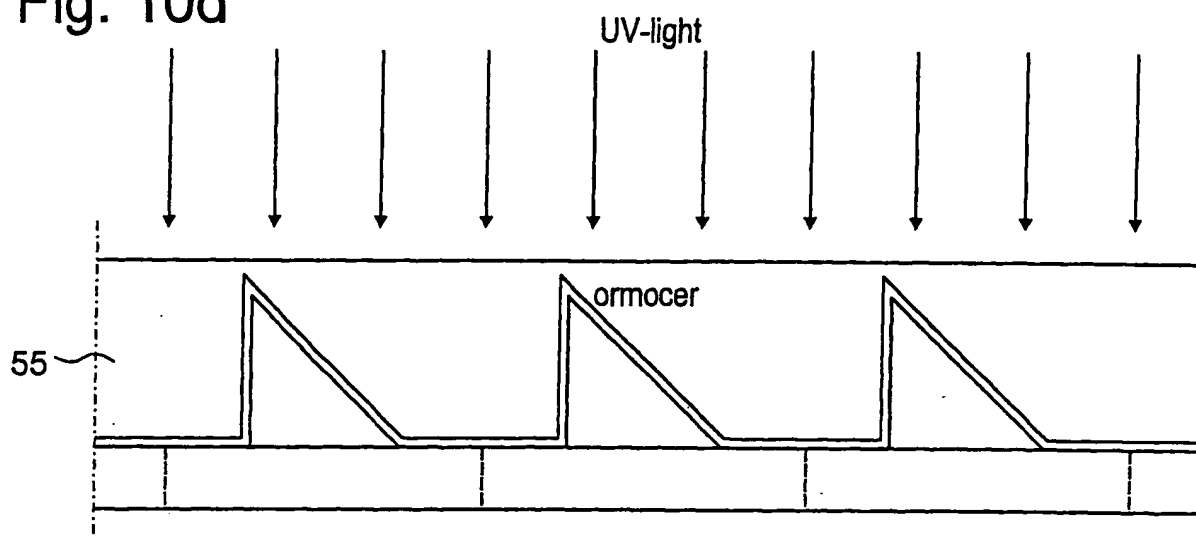


Fig. 10e

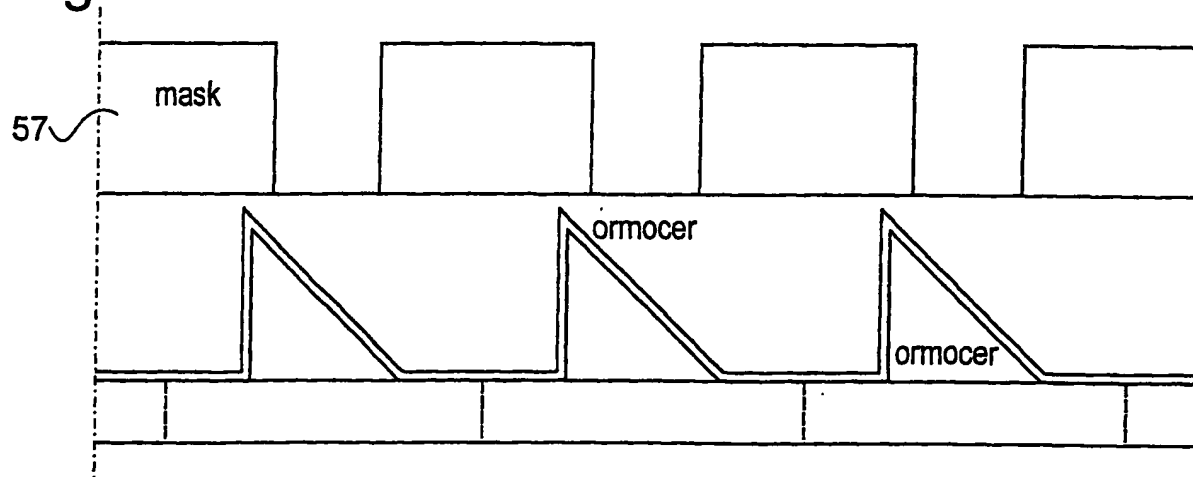
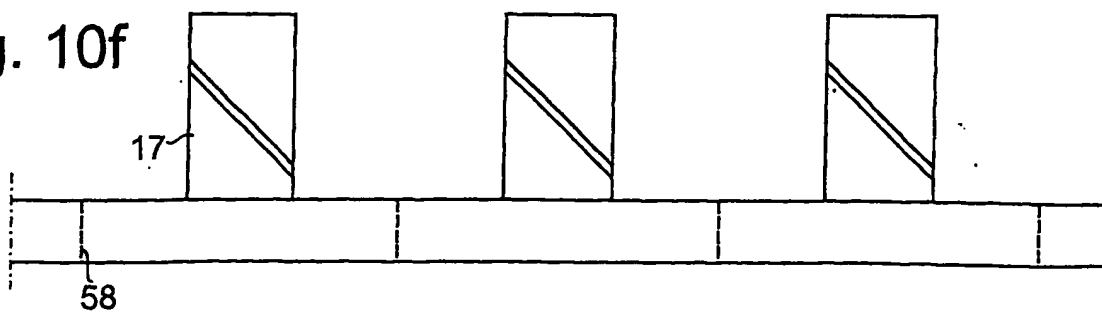


Fig. 10f



7/10

Fig. 11a

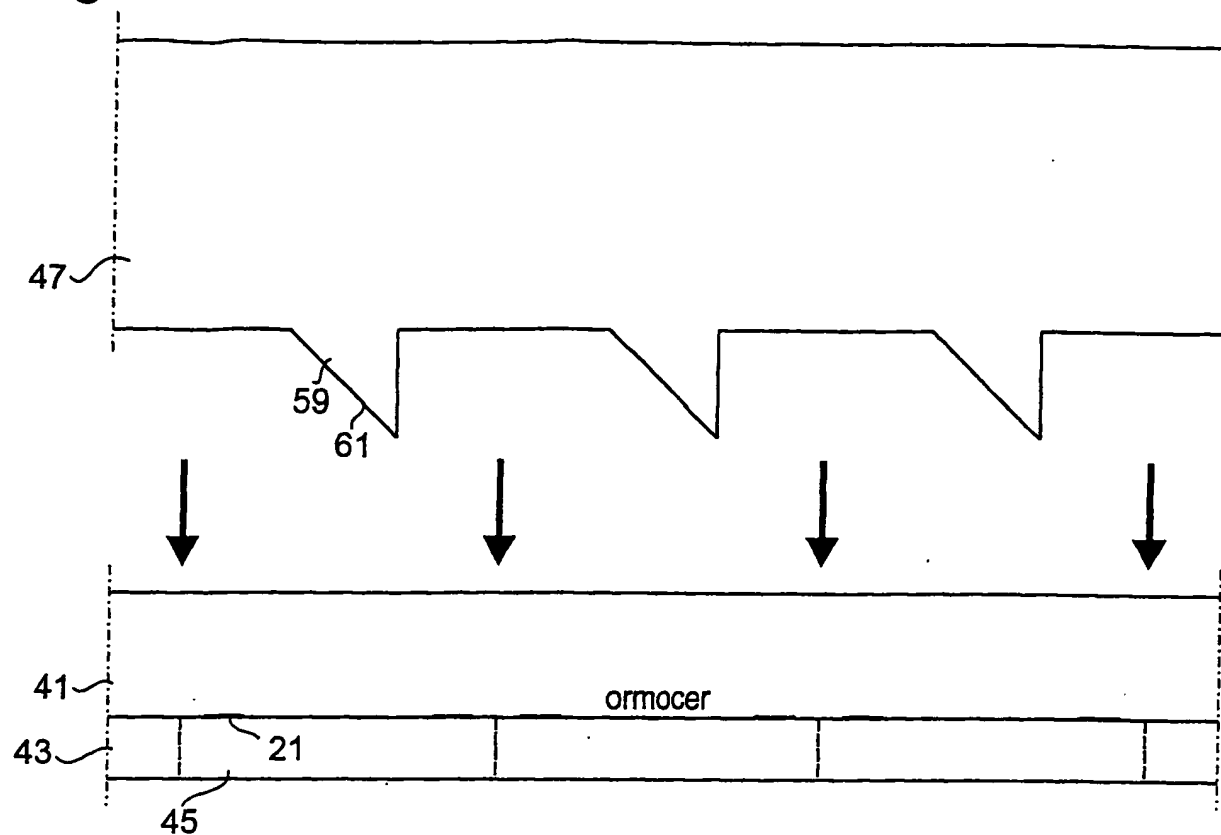
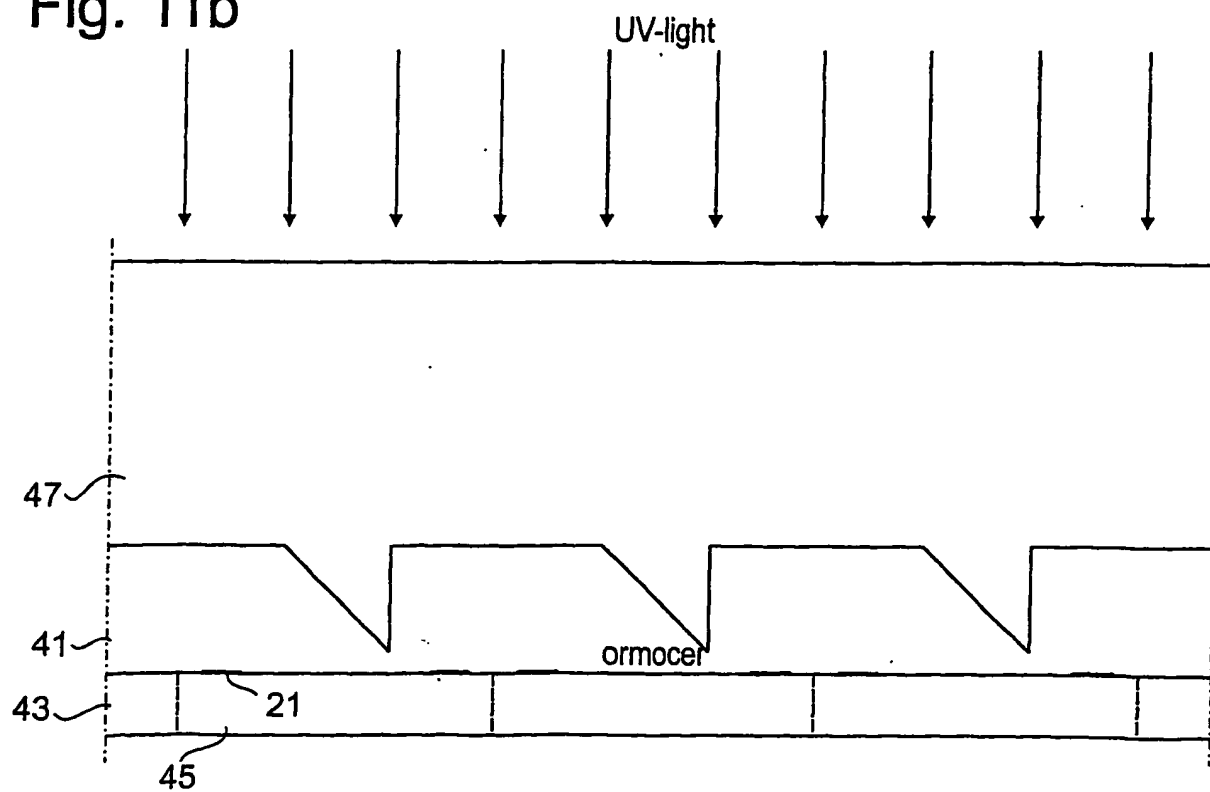
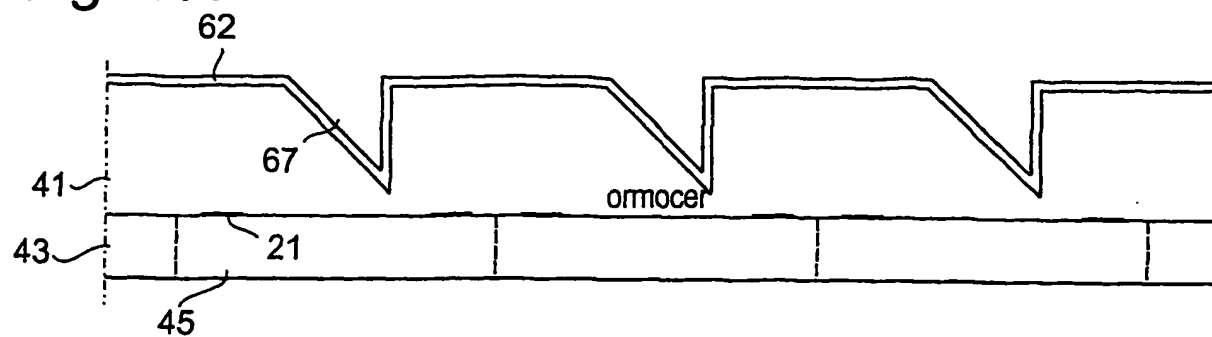


Fig. 11b



**Fig. 11c**



**Fig. 11d**

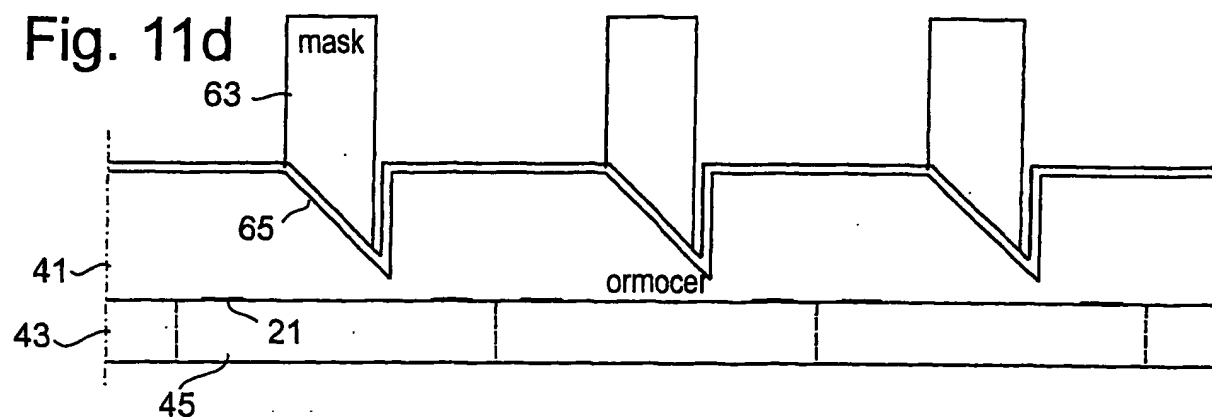


Fig. 11e

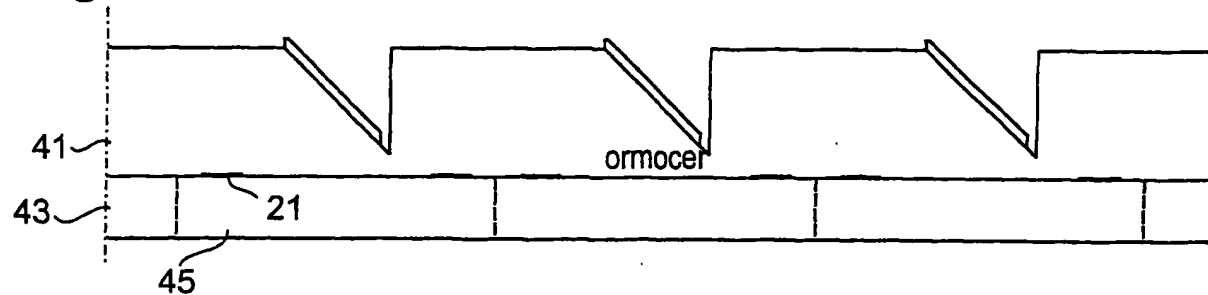


Fig. 11f

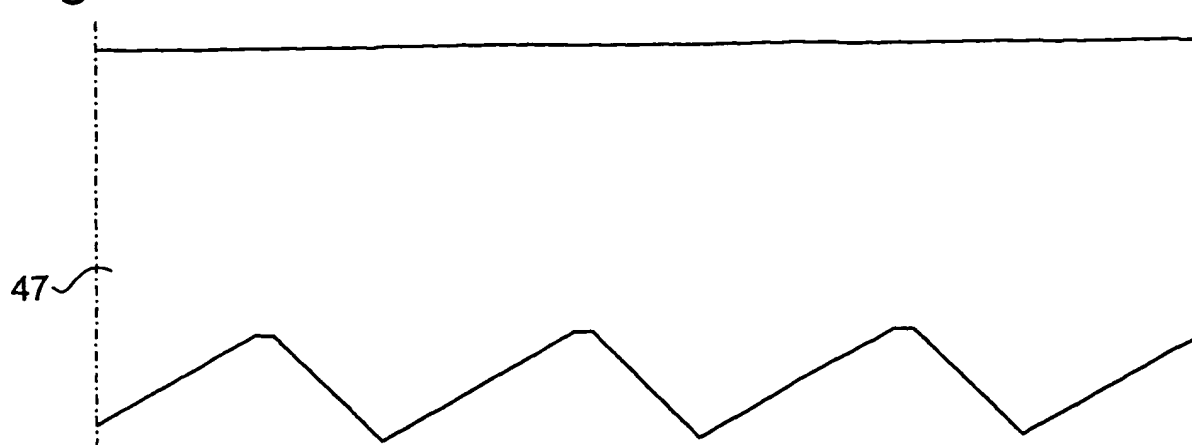
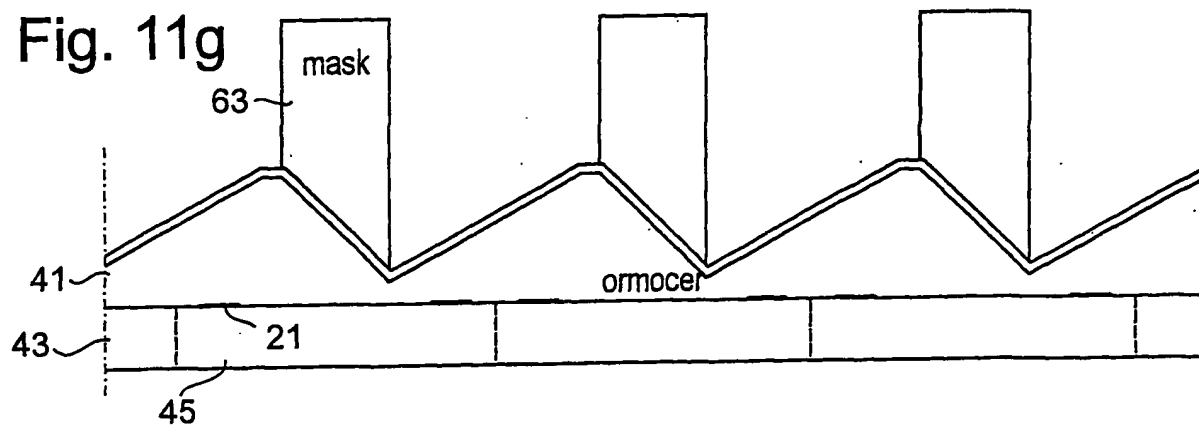


Fig. 11g





10/10

Fig. 12a

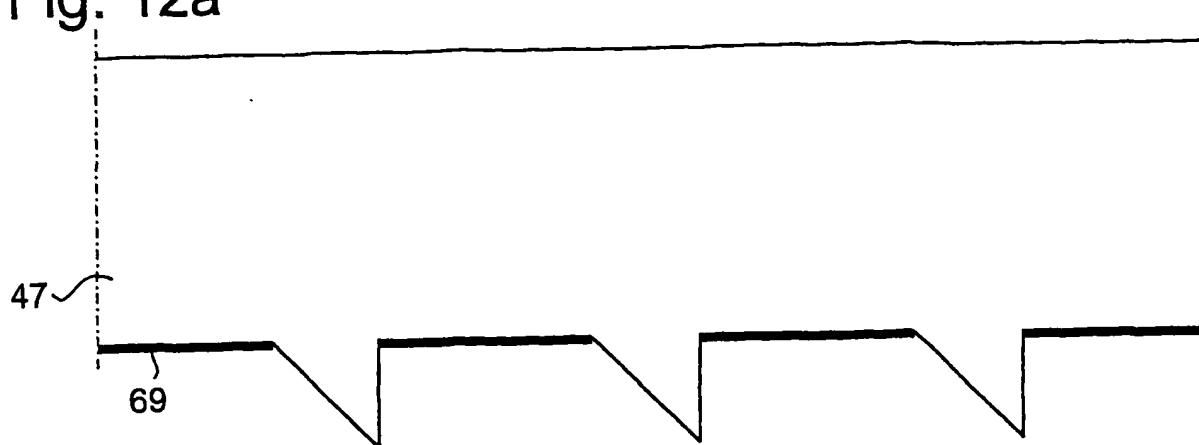


Fig. 12b

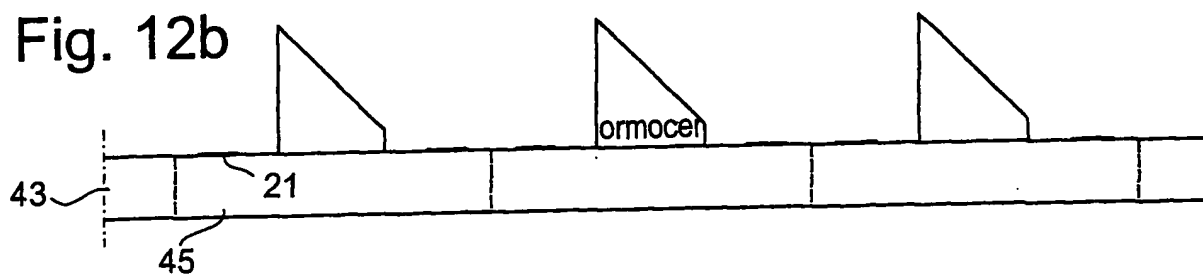
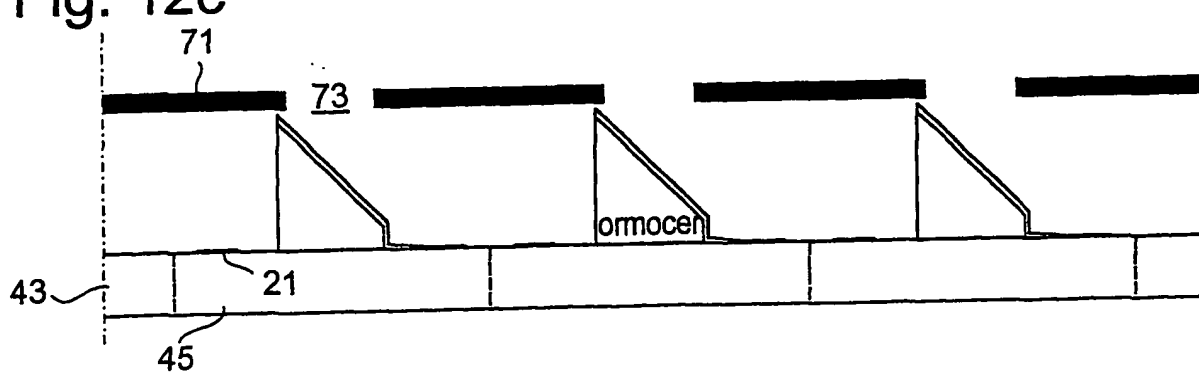


Fig. 12c



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 03/01252

## A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G02B 5/08, G02B 6/43, H04B 10/12

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G02B, H01L, H01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2276492 A (NEC CORPORATION), 28 Sept 1994 (28.09.94), page 4, line 10 - page 5, line 17, figures 1-3, claim 1	9,20
Y	--	1,20
X	US 5479426 A (NAKANISHI ET AL), 26 December 1995 (26.12.95), column 4, line 25 - column 5, line 18, figures 1a,1b, claims 1,3	1,2,5,8,10
Y	--	1,20



Further documents are listed in the continuation of Box C.



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Date of the actual completion of the international search

3 November 2003

Date of mailing of the international search report

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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 03/01252

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5793785 A (NAKANISHI ET AL), 11 August 1998 (11.08.98), column 2, line 23 - line 53; column 4, line 48 - column 5, line 4, figures 1a,1b, claims 1,3	1,2,8
Y	--	1,20
X	US 6236788 B1 (MOISEL), 22 May 2001 (22.05.01), column 1, line 49 - column 2, line 28; column 2, line 51 - column 3, line 21, figures 1-3, claims 1-6	1,19
Y	--	1,20
X	US 2002071642 A1 (NAKATA), 13 June 2002 (13.06.02), figures 1-4, claims 1,8, page 1, paragraph (0004); page 1, paragraph (0013) - page 2, paragraph (0015); page 4, paragraph (0054) - paragraph (0056)	9,11
Y	-- -----	1,20

**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

06/09/03

International application No.  
PCT/SE 03/01252

Patent document cited in search report			Publication date	Patent family member(s)		Publication date
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				JP	6295937 A	21/10/94
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US	5793785	A	11/08/98	US	5479426 A	26/12/95
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US	6236788	B1	22/05/01	DE	19845227 A	06/04/00
				EP	0990931 A	05/04/00
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US	2002071642	A1	13/06/02	WO	0120660 A	22/03/01
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